# Multiscale Simulation and Uncertainty Quantification (UQ) of Uni-directional (UD) Carbon Fiber Reinforced Polymer Composites

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PS&ED Cluster:
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Academic Disciplines:
**Mechanical Engineering**

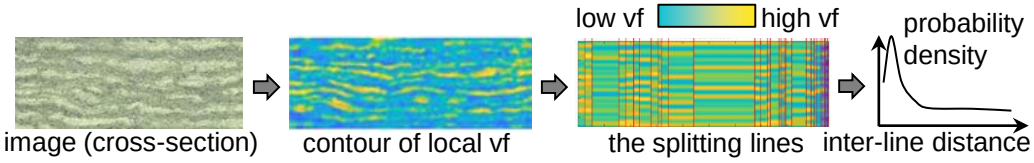
## RESEARCH OBJECTIVE

The goal of this project is to develop multiscale simulation tools that take into account the uncertainties in microstructure for the UD composite tensile test simulations with a coupon sample. At the microscale, RVEs with different microstructure were generated to investigate how RVEs effect on the microscle response of the model. At the macroscale, image-based uncertainty quantification algorithms are designed to characterize the microstructure features of the material and model their spatial correlation and stochasticity.

## MACROSCALE: IMAGE-BASED UQ

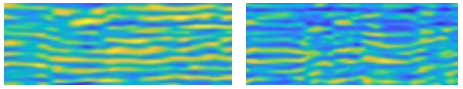
### Microstructure feature 1: fiber distribution

*Characterization*: Local fiber volume fractions (vf) are calculated from images.



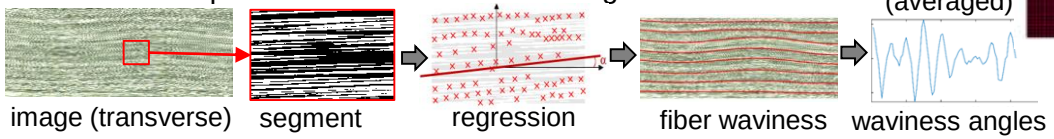

*Modeling*: Regression trees are used to encode the images. Tree nodes are vertical splitting lines and between the lines the vfs are interpolated. Random realizations are generated by sampling from the distribution of the location of the splitting lines.

random realizations



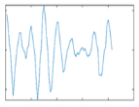
### Microstructure feature 2: fiber waviness

*Characterization*: A segmented linear regression with a customized line fitting criteria is developed to obtain the local fiber angles.

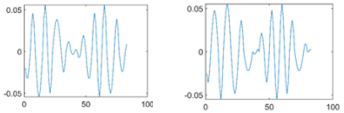


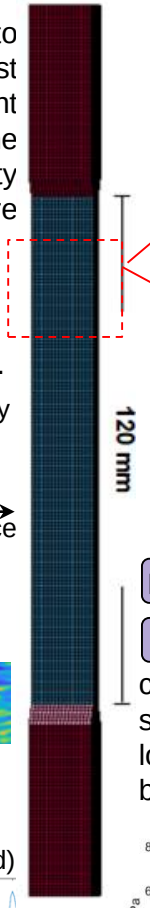

*Modeling*: The joint distribution of the half-wavelength and wave amplitude is obtained from the images. Random realizations are generated by sampling from the joint distribution.

waviness angles from the image



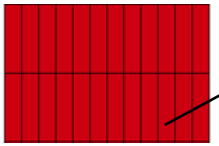
random realizations



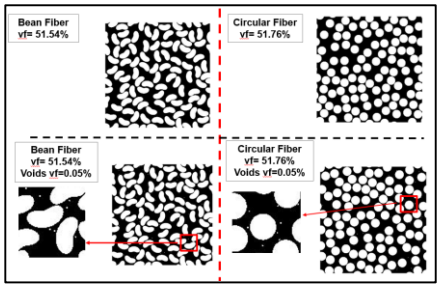



## MICROSCALE SIMULATION

Based on the experimental data, UD RVEs are generated to implement at each gauss point. Fast fourier transformation (FFT) method is used in the microscale.



Thickness direction in the macroscale (different RVE can be used at each gauss point)

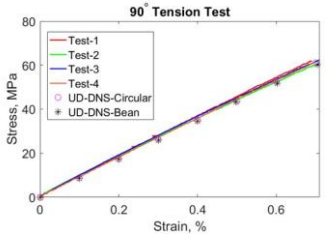



RVEs used in each gauss point

### Comparison between circular and bean shape RVE

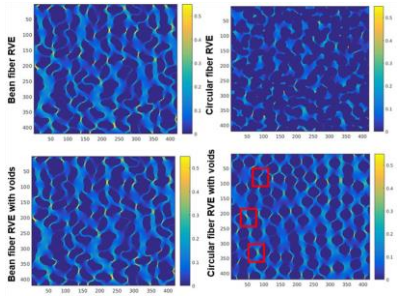
**Elastic** → no notable effect is observed

**Plastic** → bean shape fibers and voids induce stress concentration around each fiber resulting in higher plastic strain. Since damage initiates and propagates in the high localized plastic strain region, strength is deteriorated with bean shape fibers.




elastic response of RVEs vs experiments using FFT (PBC* transverse tension)

* Periodic Boundary Condition




equivalent plastic strain contour used in the plastic behavior study using FFT (PBC transverse shear)